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DESIGNING DISTRIBUTION GRID TARIFFS FOR A CARBON-NEUTRAL FUTURE

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Extended Abstract

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Abstract Summary

Residential flexibility is often regarded as unreliable and weakly controllable and is therefore absent from long term energy scenarios. Nevertheless, as electrified mobility and heating proliferate and smart home technologies become widespread, residential flexibility is likely to materialize at scale.
While households increasingly respond to wholesale price signals, coordination of these decentralized responses with distribution grid constraints remains a governance challenge. Distribution level locational marginal pricing (LMPs) could provide efficient coordination, but implementation is hindered by complexity, cost, and social acceptability. In their absence, alternative instruments are needed to manage local congestion.
This paper takes a necessary intermediate step by evaluating grid tariff designs as coordination mechanism for residential flexibility. We develop a transformer level model of household electricity demand and supply under 2040 wholesale price assumptions, explicitly accounting for electric vehicles, heat pumps, photovoltaics, batteries, and heterogeneous flexibility. Household schedules are optimized by intelligent home energy management systems, while grid reinforcement is endogenously determined based on transformer capacity constraints.
Our results show that when households fully exploit market driven flexibility, transformer capacity becomes a major bottleneck, requiring substantial reinforcement in the absence of corrective incentives. We find that conventional capacity tariffs applied only to consumption are insufficient to mitigate congestion when injections remain unpriced. In contrast, symmetric, capacity based tariffs applied to both consumption and injection substantially reduce overloads, defer transformer investments, and yield the highest welfare, with savings of up to €110 per household annually.
These findings demonstrate that capacity reflective grid tariffs can govern residential flexibility, while uncertainties remain around long term investment incentives. The analysis provides a foundation for future comparisons of tailored tariff schemes with LMP based approaches in deeply decarbonized electricity systems.

Presenting Author Biography

Dr. Joachim Geske is an energy economist with over 20 years of experience in the analysis and modeling of complex energy systems. He is currently a Research Scientist at the University of Luxembourg, where his work focuses on energy markets, residential flexibility, storage, and infrastructure governance in deeply decarbonized systems. Dr. Geske previously held research positions at Imperial College London and Forschungszentrum Jülich. His research has been widely published in leading international journals, including *Energy Economics*, *Energy Policy*, and *The Energy Journal*. He has led and contributed to numerous national and international research projects on energy systems and policy.